Nuclear Energy and Waste Program

EVALUATION OF UNCERTAINTIES DUE TO HYDROGEOLOGICAL MODELING AND GROUNDWATER FLOW ANALYSIS: STRATEGY FOR CHARACTERIZING A NEW SITE

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RESEARCH OBJECTIVES

It is quite challenging to build a reliable model for simulating groundwater flow in a large body of rock mass, particularly when the rock is fractured. Large-scale groundwater flow models are typically calibrated to the steady-state pressure head data. However, steady-state head data alone are not sufficient for building a reliable predictive model. The overall objective of this project is to develop methodologies for reducing the uncertainty and increasing the reliability of such a model. In the present work, we develop a strategy for characterizing a new site where a minimal number of wells are available.

APPROACH

We begin with a 9 km × 9 km × 2 km thick effective continuum model of the fractured rock of the Tono, Japan, area developed from regional geographic, geologic, geophysical, and surface and subsurface hydrological data. The model is calibrated simultaneously to data from 17 wells: steady-state head profiles in 11 wells, 21 pressure transients from 8 wells, and steady-state temperature profiles in 11 wells, which constrain the porosity and permeability of the granitic rock, overlying sediments, and a major subvertical fault that bisects the model. Also so constrained are the amount of surface infiltration that recharges the deep groundwater flow system and the lateral boundary conditions of the model. The resulting model is considered the best model possible of the Tono region, since it utilizes the full set of available data.

Next, we consider data from various subsets of these 17 wells and compare performance measures obtained from the resulting models to those of the best model, to investigate how many wells to use and how to optimally locate wells for a preliminary site characterization. Additionally, some of the key assumptions regarding model heterogeneity and boundary conditions are examined to assess the impact they have on recommended well locations.

ACCOMPLISHMENTS

We find that, for the most part, our understanding of the regional groundwater flow and advective tracer transport does not improve significantly as more and more wells are used for site
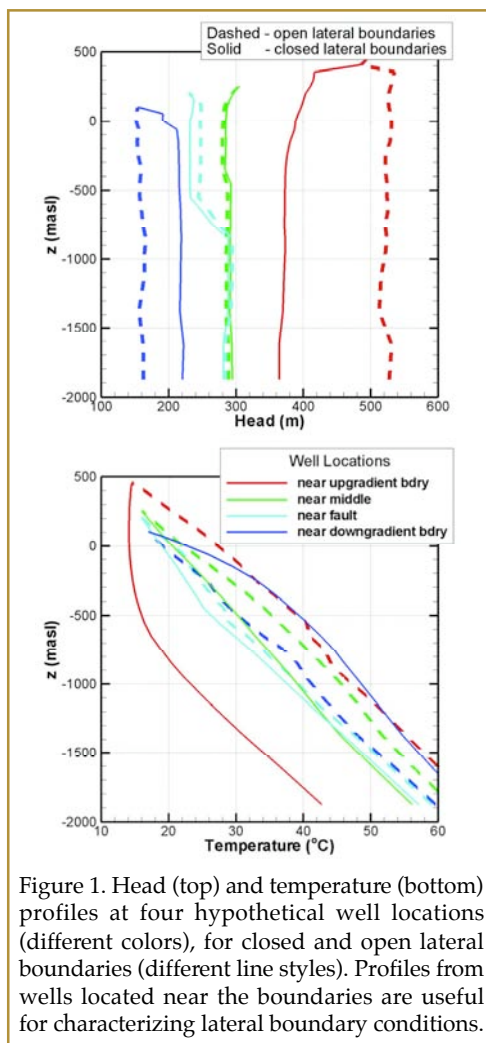

Figure 1. Head (top) and temperature (bottom) profiles at four hypothetical well locations (different colors), for closed and open lateral boundaries (different line styles). Profiles from wells located near the boundaries are useful for characterizing lateral boundary conditions.

characterization. This is because these measures are controlled by surface topography, surface and lateral boundary conditions, and permeability and porosity distributions, and the present property distributions have short correlations, hence using one well for site characterization provides as much information about material properties as using many wells does.

On the other hand, observing head profiles in more wells increases the probability that large-scale features that do impact groundwater flow (such as a fault) can be identified. An additional caveat is that if the permeability distribution has long-range correlations, then a small number of wells are not as likely to provide a representative sample of rock properties, nor a true picture of the regional groundwater flow.

SIGNIFICANCE OF FINDINGS

Lateral boundary conditions have a large impact on all aspects of flow and transport. If existing studies of topography and regional groundwater flow do not provide this information, wells should be located near the presumed upgradient and downgradient boundaries of the site, and head and temperature profiles should be examined for the characteristics of closed and open groundwater flow systems.

RELATED PUBLICATION

Karasaki, K., J. Apps, C. Doughty, H. Gwatney, C.T. Onishi, R.C. Trautz, and C.F. Tsang, Feature Detection, Characterization and Confirmation Methodology—Final Report. NUMO-LBNL Collaborative Research Project Report, March 2007.